Case for ACE Radiometers - Basic Notions

Goddard
Space
Flight Center

ACE Objective: **Quantify aerosol-cloud interaction and assessing the impact of aerosols on the hydrological cycle**. Cloud-aerosol processes are major portion of climate forcing uncertainty.

Step #1 => get the clouds right

Step #2 => get the aerosols right

Practical ACE objective: do better than A-Train (MODIS + C&C)

Global Aerosol & Cloud Observations: State-of-the-art passive remote sensing (ir & vis) needs further advancement and capability (ice phase).

Polarimeter

Submillimeter + Infrared

CALIPSO & CloudSat are transforming cloud retrieval science, but do not providing global coverage. Nadir limited. Moreover, the physics of passive vis & ir remote sensing has not changed.

ACE Radiometers

What radiometers?

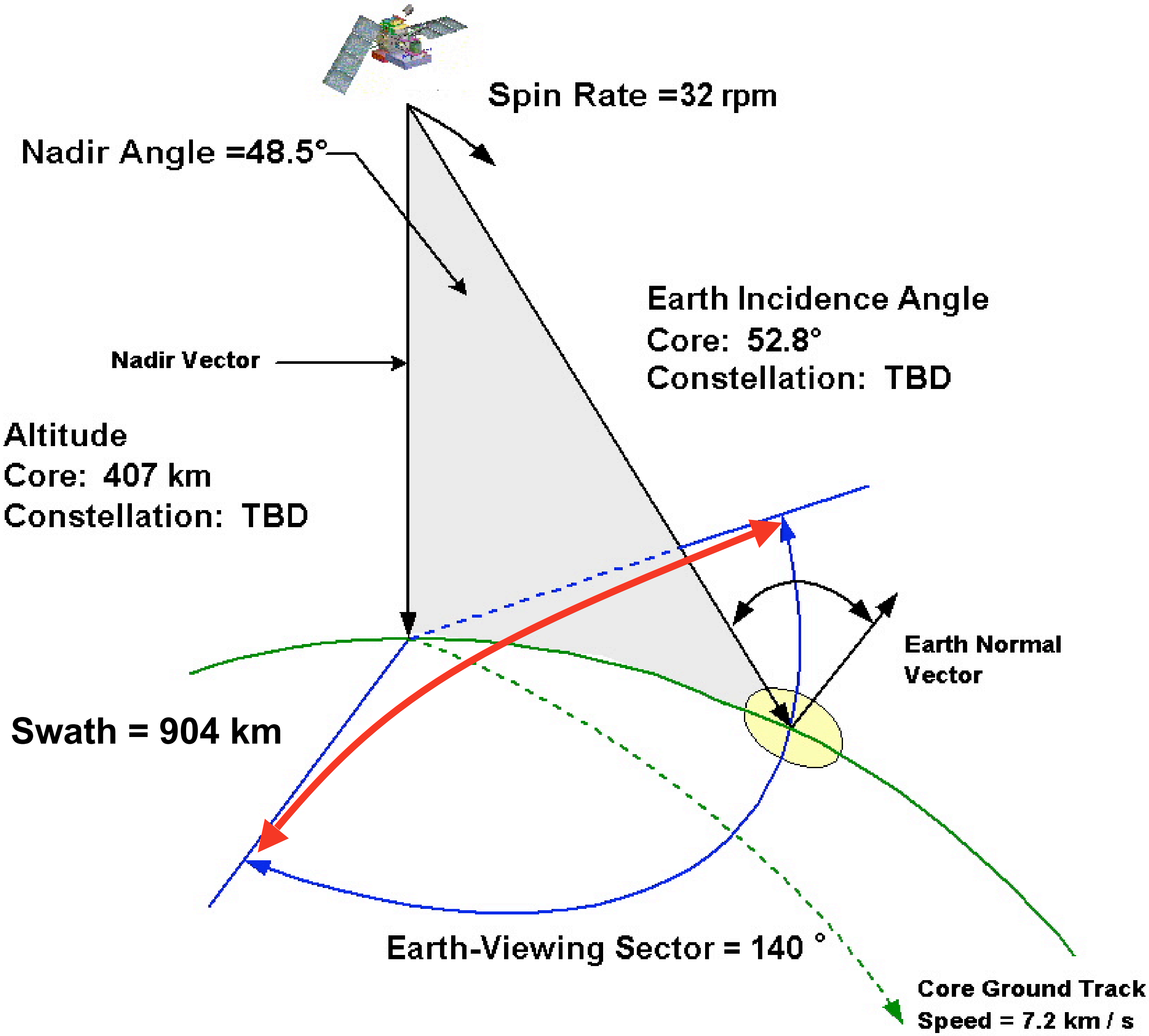
GMI-like conically scanning microwave radiometer

- Precipitation Rate
- Cloud Liquid Water Path
- Column Water Vapor Path
- Surface Wind Speed
- SST

48.5° off-nadir => 904 km swath at 407 km altitude

Nominally ~10 km resolution

GMI Observation Geometry



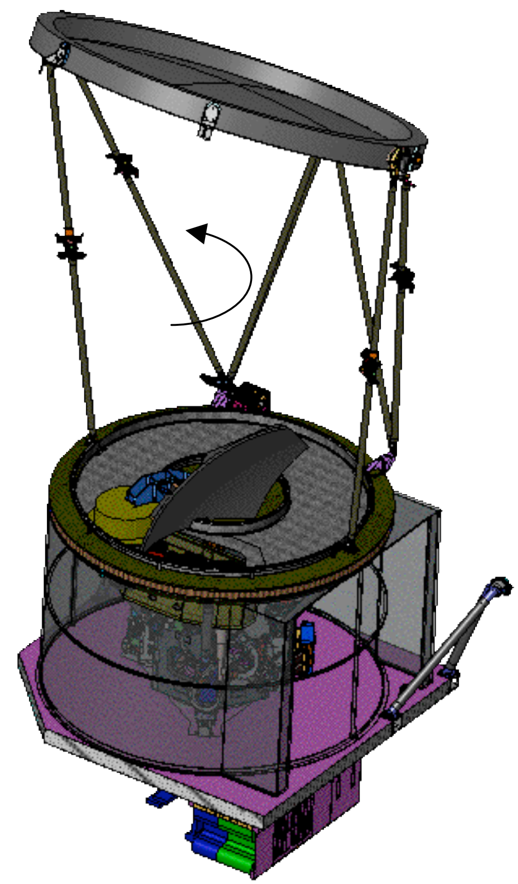
Low Frequency μ-wave Radiometer (GMI)

GPM Microwave Imager (GMI) Key Products

- Rain rates from ~0.3 to 110 mm/hr
- Increased sensitivity to light rain over land and falling snow

ACOB-B would be a GPM daughter satellite

Ball Aerospace and Technology Corporation (BATC) is developing GMI



GMI Key Parameters

Mass (with margin):~150 kg
Power:~125 W
Data Rate:~30 kbps
Antenna Diameter:~1.2 m
Channel Set:
10.65 GHz, H & V Pol
18.7 GHz, H & V Pol
23.8 GHz, V Pol
36.5 GHz, H & V Pol
89.0 GHz, H & V Pol
166 GHz, H & V Pol,
183±3 GHz, V (or H) Pol
183±8 GHz, V (or H)
(166 and 183 GHz to have same resolution as 89 GHz)

Same freq. as HF radiometer

ACE Radiometers

What radiometers?

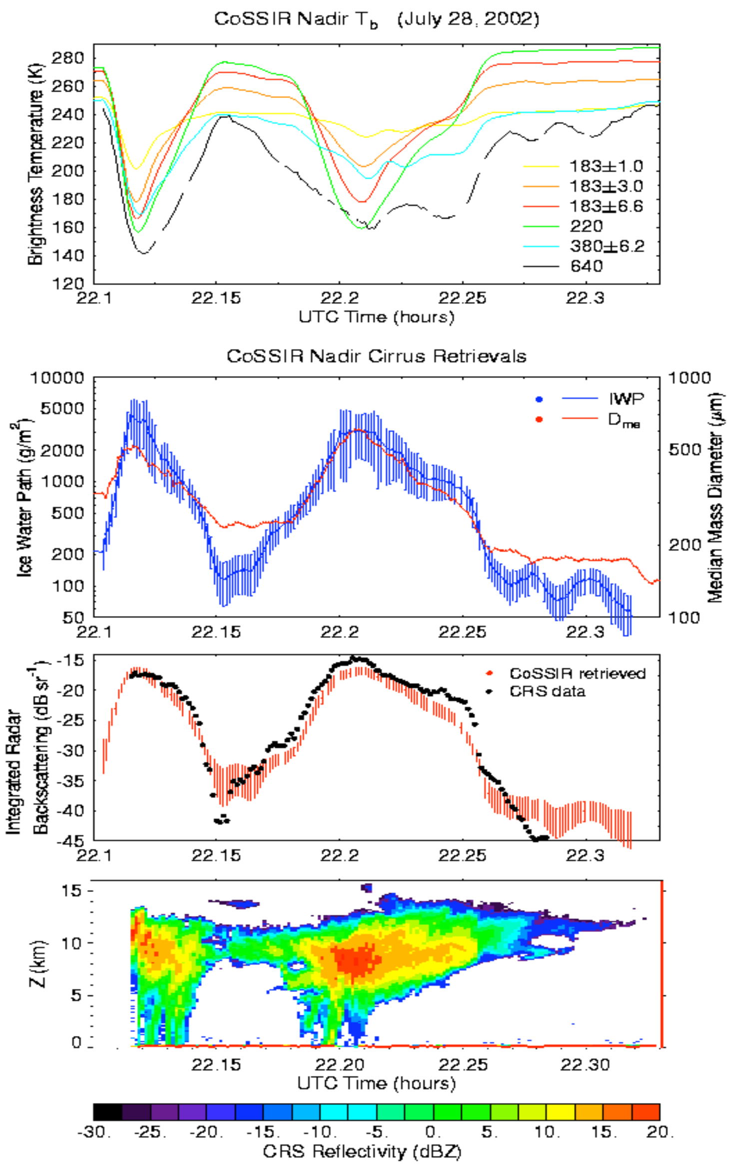
Submillimeter/millimeter conically-scanning radiometer
+ Pushbroom IR Radiometer

Vertically-integrated Ice Water Path (IWP)
Weighted Mean-Mass Ice Particle Diameter (D_{me})

45° off-nadir => ~1300 km swath at 650 km altitude
Nominally ~10 km resolution (SM4)

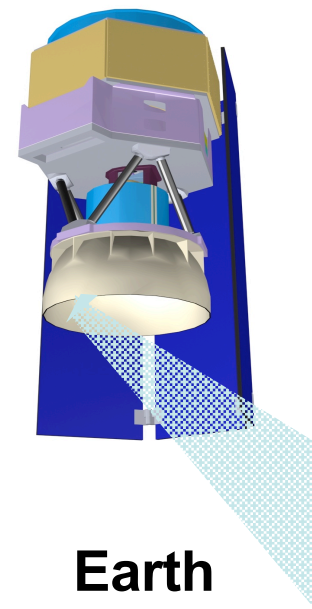
Cloud Height (stereo IR, 0.6 km resolution)
Water Vapor Profile (SM4)

High Frequency μ-wave Radiometer (SIRICE)



Submillimeter/Millimeter (SM4) Radiometer

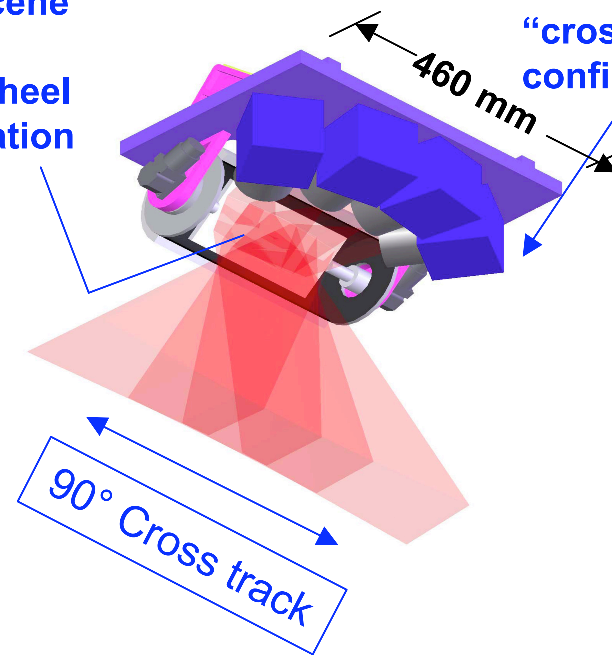
- Conical Scanning Imager
  1300 km swath @ 650 km
- 10-km spatial resolution
  0.36∞ pencil beam
- 6 Receivers, 12 Channels
  183V, 325V, 448V,
  643 V&H, and 874V GHz}
- Three-point calibration
  hot, cold, space



- Heritage: MLS, HERSHEL, MIRO
- Airborne Simulator: CoSSIR

Infrared Cloud Imaging Radiometer (IRCIR)

- Infrared Cloud Imaging Radiometer
  - 4 cameras give 90° wide swath cross track coverage (pushbroom) in cross-eyed configuration that shares paddle wheel mirror
  - Cloud properties from 3 narrow spectral bands (12, 11.5, 8.5 µm) in near nadir (6°) view
  - Stereo cloud height - 25° forward view
  - 600-m nadir footprint
  - Cloud height to ~600 m
  - Uncooled microbolometer technology (640 x 480 pixel array in each camera)
  - Cameras share single on-board blackbody for calibration
- Heritage
  - Infrared Spectral Imaging Radiometer (STS-85)
  - THEMIS (Mars Odyssey)
  - COVIR: Code Y Instrument Incubator Program at GSFC



IRCIR Characteristics

Mass:	67.7 Kg*
Dimensions:	52.5 x 45 x 33 cm + 30 x 30 x 28 cm
Power:	60.9 W*
Data Rate:	2.2 Mbps (1.1Mbps 2:1 compression)

*including 30% margin

Case for ACE Radiometers - Science Pathways

Key observing system attributes for aerosol-cloud science advancement

Cloud-resolving observations (1-10 km)

consistent with fundamental scales of cloud structure/physics

Cloud-system resolving observations (100's km swath width)

- enhances statistical sample robustness & context
- enables case study approach & robust compositing
- enables global data assimilation pathway (Earth System)
- enables regional, seasonal, phenomenological distinctions

Global Coverage is essential for Earth System Science

Case for ACE Radiometers - Observables

Key observing system attributes for science advancement

Describe the entire cloud system, both the hydrologically active clouds (e.g., deep convection) and radiatively active clouds (cirrus, stratus)

Precipitation	Microwave
Cloud Liquid Water	Microwave
Cloud Ice Water	Submillmeter + IR
Water Vapor	Submillmeter

Enables description of fundamental **coupling of hydrologic and energy cycles from cloud to global scales** - a BIG deal !!!

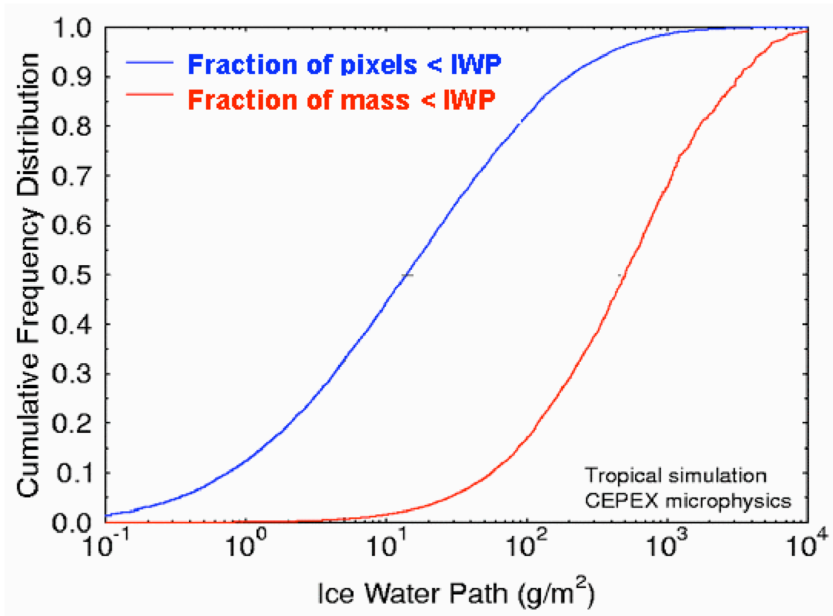
Hydrologic Component :: 20% of clouds contain more than 90% of the ice

Radiation Component :: 80% of the clouds have less than 100 g m^{-2}

What do we need to measure?

80% of the ice clouds have an Ice Water Path (IWP) less than 100 g m^{-2}

20% of the clouds contain more than 90% of ice

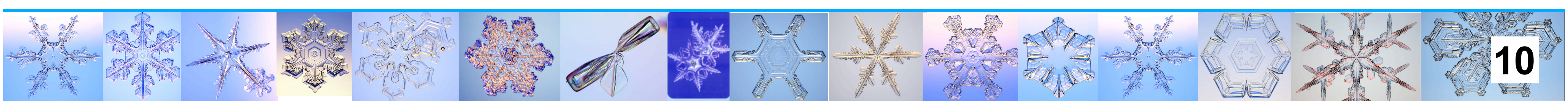


$\sum(N_{IWP} < N_{IWPo})/N_{IWPtotal}$

$\sum(IWP < IWP_o)/IWP_{total}$

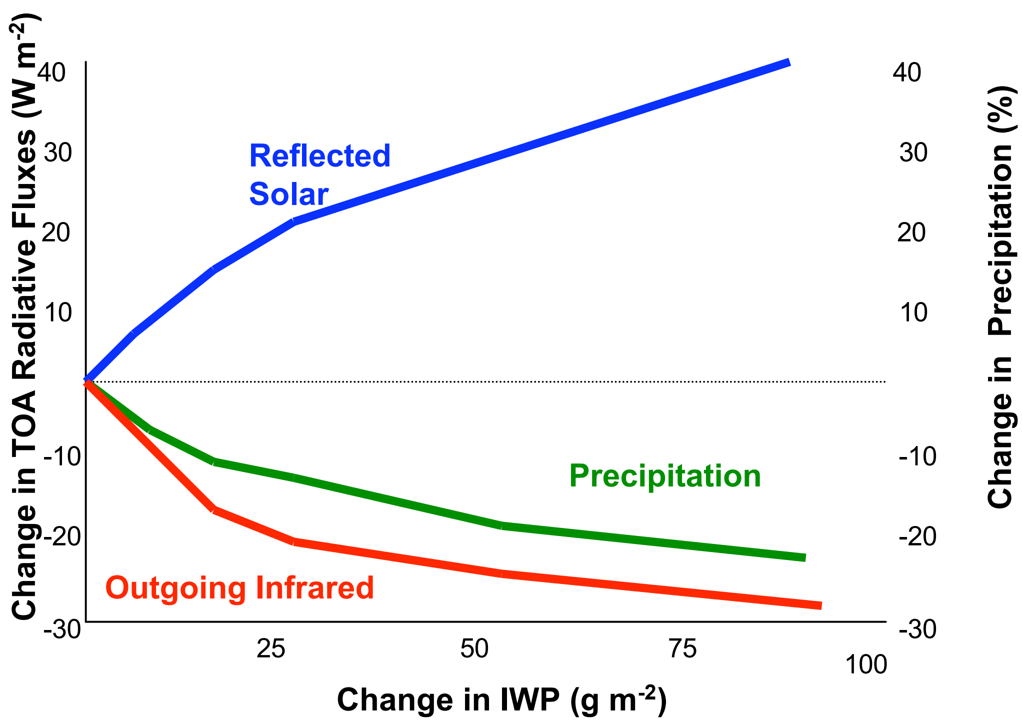
Ice water path: IWP - vertically-integrated (column) mass of ice particles per unit area, => the Earth's Radiation Budget and linkage to the Hydrologic Cycle.

Weighted mean mass particle diameter (Dme). Crystal size => cloud radiative properties and ice crystal fall speed (vertical ice mass flux), a key model parameter.



Is Cloud Ice Really That Important ?

Global cloud ice measurements are essential for understanding the coupling of the global hydrologic and energy cycles.



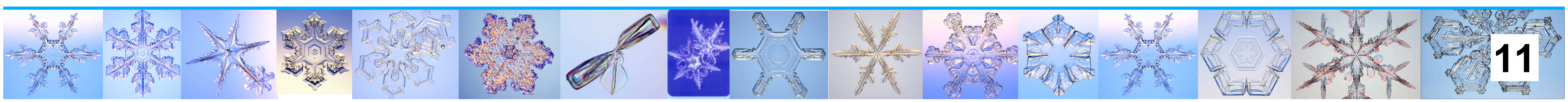
The sensitivity of GCM tropical radiative and precipitation fields to IWP (GFDL GCM).

It's a budget…..

If you change Precipitation, you change the IWP :
=> less rain, more ice

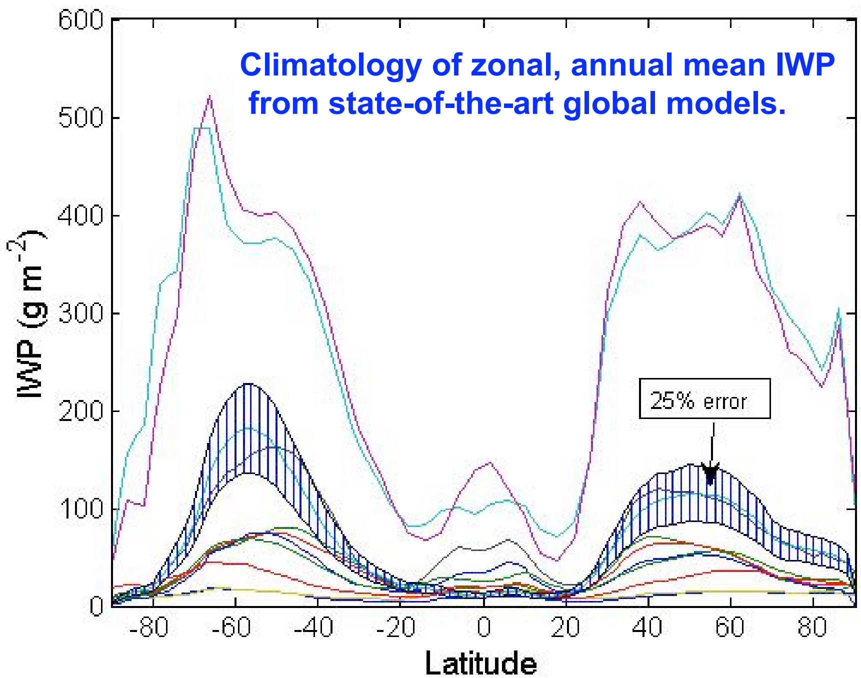
If you change the IWP, you change the Earth's radiative energy budget:
=> more ice, brighter planet,

=> more ice, colder planet, …but warmer surface?



What is our current knowledge?

The large discrepancy in mean IWP between climate models is one demonstration of our poor knowledge of ice mass in the atmosphere.



Estimates of global mean annual IWP range from 20 to 150 g m^{-2} !!!

Ice clouds are largest remaining unconstrained tuning knob left to GCM's to achieve mutual agreement with observations of global radiation budget (ERBE, CERES) and global precipitation (AMSR-E, TRMM, GPM)

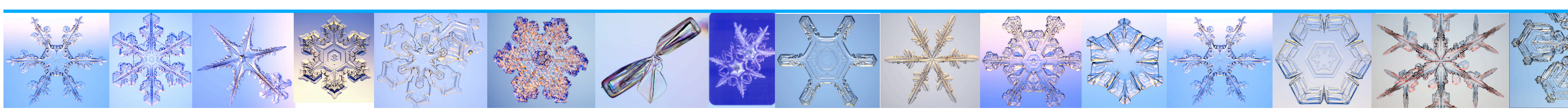
IWP must be measured to an **accuracy of ±25%** (NIST-NOAA-NASA Workshop on Satellite Instrument Calibration for Measuring Global Climate Change; Ohring et al (2004)). Only CloudSat approaches this accuracy.

MODIS/AIRS achieves limited dynamic range (less than a few hundred g m^{-2})

MLS does not include optimal channels and has very coarse resolution (limb scanning).

CloudSat nadir view greatly limits sampling.

But all are nevertheless doing IWP !!!



ACE Radiometers

CRM's are viewed, by some, as the salvation of Global Models with respect to clouds, either for parameterization development (GCSS) or directly via MMF.

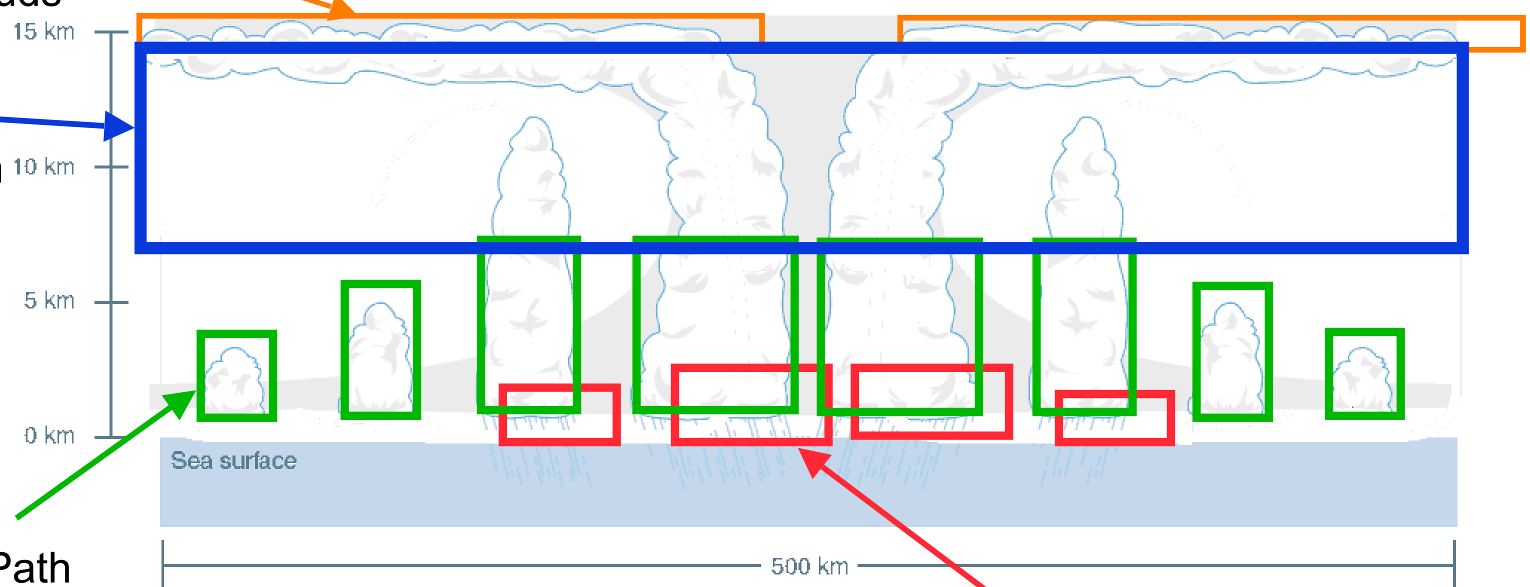
……BUT, even CRM's are unconstrained with respect to ice processes!!

Unique Measurements of Hydrological Cycle

Measure key components of the hydrological cycle

Infrared – thin clouds
Solar – top of clouds

SIRICE –
Ice Water Path



Microwave –
Liquid Water Path

Microwave - Precipitation

ACOB: Two Spacecraft Observing Geometry

Goddard Space Flight Center